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Text Recognition of Cardboard Pharmaceutical Packages by Utilizing Machine Vision

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Abstract

In this paper, text recognition of variably curved cardboard pharmaceutical packages is studied from the photometric stereo imaging point-of-view with focus on developing a method for binarizing the expiration date and batch code texts. Adaptive filtering, more specifically Wiener filter, is used together with haze removal algorithm with fusion of LoG-edge detected sub-images resulting an Otsu thresholded binary image of expiration date and batch code texts for future analysis. Some results are presented, and they appear to be promising for text binarization. Successful binarization is crucial in text character segmentation and further automatic reading. Furthermore, some new ideas will be presented that will be used in our future research work.

Introduction

The global pharmaceutical packaging industry market value in 2017 was USD 63 Billion and is projected to reach USD 101 Billion by the end of 2023 [1]. All finished medicinal products should be identified by the labels required by national law, including the expiry date in uncoded form and the batch number provided by the manufacturer [2].

Automation and robotics are also spreading to prescription drug delivery in pharmacies and hospitals, where they can, for example, increase the efficiency and ease of shelving and collection of medicine packages. Automated dispensing system organizes and automatically arranges prescription drugs, thus optimizing the inventory cycle. In the event of manufacturers safety recall, the associated packages included in the batch leave the dispensing system automatically. The expiration date and batch code of the packages are read and stored manually from packages that do not contain a 2D-data matrix. By automating the reading and storage of expiration dates and batch codes of medicine packages, staff is freed up for customer service and medication counseling.

Optical character recognition is based on pattern recognition in which patterns of bright and dark pixels identified from documents are compared to a model taught to the system. Curved surfaces of cardboard medicine packages illuminate unevenly in the camera's view, causing a challenging problem for OCR.

Therefore, more targeted and efficient methods need to be developed to binarize expiration date and batch code texts without noise and defects from the medicine packages surface enabling texts segmentation and optical character recognition.

Our novel method uses four images taken of package from a fixed position illuminated from four different lighting sources at different angles. Wiener filtering allows to smooth images without changing the text characters. Image edges are detected, and final image is formed by merging each sub-image edges which are further binarized. Method enables recognition of texts in varying places also from packages curved surface without noise and defects.

Our results: In this paper, we study the recognition of variably curved cardboard pharmaceutical packages texts from photometric stereo imaging point-of-view with focus on developing a novel method for binarizing the expiration date and batch number in a noise-free and defect-free on the surface of the package. We use the sub-images Wiener filtering together with a haze-removal algorithm and image fusion of Laplacian of Gaussian edge detected sub-images to process noise-free and defect-free binarization of texts located on curved unevenly illuminated package surfaces. Moreover, we present some results that seem very promising for binarizing texts. Furthermore, we present some new ideas that will be used in our future research work.

The structure of the paper is as follows. Section II provides a brief introduction to optical text recognition in the extent which it serves the extraction and binarization steps of text characters performed in this research work. Section III discusses about text recognition of cardboard pharmaceutical packages. In section IV achieved results are presented and discussed. Finally, section V concludes the paper and outlines our future research work ideas.

Optical Text Recognition

Today, papers are increasingly being replaced by electronic methods. Electronic devices are used more to copy, scan, send, and store documents than ever before. The reason for their popularity is that devices provide easy and fast access to future information retrieval. Optical Character Recognition (OCR) is a technology that can automatically extract text from scanned images into machine encoded form. OCR improves the human-machine interface in many applications, for example, by enabling text storing and editing, searching for a word or phrase, and in text mining related use cases.

OCR works by recognizing a pattern of bright and dark pixels in a document scanned by a digitizer which can be a scanner or camera. Traditional optical character recognition method attempts to recognize text characters from patterns in a digitized image by comparing the identified patterns to internal models in the system. Method tries to identify a character in the pattern which can be a letter, number, or some special character. When characters form a group, this group is compared to words in grammar in which the correctness of the identification can be deducted automatically. Depending on the application, the character recognition process of the OCR system can include three main steps: preprocessing, feature extraction, and classification. Result of OCR is crucially affected by the quality of the scanned documents [3, 4]

Text Recognition of Cardboard Pharmaceutical Packages

Recognition of texts printed on medicine packages differs from OCR in documents because the target surface is not always flat but curves outwards. On curved target surfaces, the patterns seen by the sensor are distorted due to changes in the surface shape of the package, surface color changes, and surface shape changes caused by text printing techniques. In addition, text is placed in different positions on the packages surface facing the camera, making it impossible to recognize text characters with standard OCR.

During our research work we developed an algorithm whose image analysis is based on an adaptive filtering and haze removal algorithm with fusion of edge detected sub-images. The result is a binary image of the expiration date and batch code texts, thresholded by the fused image using the Otsu method. The new developed method is robust and binarizes even text characters placed on a curved surface. In the following, we review the parts of our novel image processing algorithm.

A. Adaptive Filtering

At the beginning, sub-images are filtered with an adaptive filter which eliminates image noise, smooth out the background texture of images, and enhance the contrast between the background and text areas of the images [6]. For this, the Wiener filtering method, which is based on the statistics estimated from a 2x2 neighborhood of each pixel, was used. In this way, the areas of the text characters in the image are not smoothed, but the areas with smaller variances are smoothed more strongly. Figure 1 shows the images Wiener filtering principle.

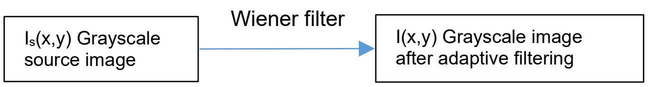


***Figure 1**. Principle of images Wiener filtering.*

Wiener filter is optimum filter, which main objective is to minimize mean square error between the estimated random process and the desired process [5]. Each grayscale source image I_s is transformed to the filtered image I according to Equation 1 [6]:

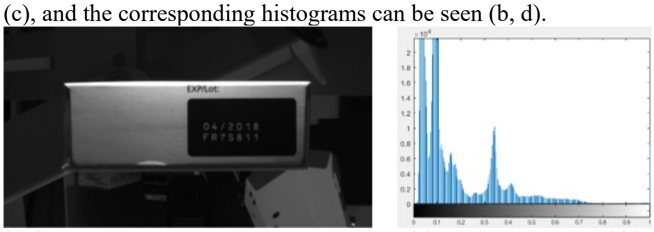
$$I(x, y) = \mu + (\sigma^2 - v^2)(I_s(x, y) - \mu) / \sigma^2 \quad (1)$$

Where μ is local mean, σ2 is the variance of each pixel at 2x2 neighborhood, v2 is the average of all estimated variances for each pixel in the neighborhood.

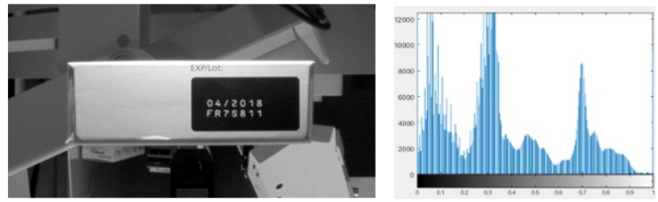
B. Haze Removal Algorithm

The source images were taken in low light and the texts in them are difficult to recognize due to the changing color and the changing target surface color of the package, which is often convex. Since the performance of the feature extraction, filtering, and photometric analysis algorithms inevitably suffered from biased and low-contrast scene radiation [7, 8], an evaluation of the effect of the haze removal algorithm on text characters binarizing accuracy was included in the study.

The method used works by inverting the image at first, then reducing images haze with a dehazing operation and finally inverting the result to obtain the enhanced image [9]. In Figure 2, the source image (a), the inverted and haze removal processed image (c), and the corresponding histograms can be seen (b, d).



(a) Source image (b) intensity histogram of (a)



(c) inverted, haze removal processed image (d) intensity histogram of (c)

***Figure 2**. Effect of haze removal algorithm with histograms.*

Histogram shapes have similarities, however pixels of the source image are in the histogram minima region, while in the histogram of the image processed by the haze removal algorithm, the pixels also even out into region of higher intensities.

C. Edge Detection

Next in our novel image processing algorithm is sub-images edge detection. For that, we use rotationally symmetric Laplacian of the Gaussian operation. It works by first removing image noise by Gaussian filtering and then detecting the edges of image objects with the Laplacian operator. Gaussian smoothing reduce methods sensitivity to noise as the Laplacian operation as second derivative method highlights the regions of rapid intensity changes in the image [10]. Result of edge detection operation is an image with text character boundaries zero crossings. In our experiments, we concluded that the 5x5 sized Gaussian filter and sigma value 0.5 for standard deviation values suited best for sub-images edge detection.

D. Image Fusion

Each edge detected sub-image represent zero crossings of the boundaries of the text character candidates. Background of the obtained images are dark and recognized foreground object edges are bright. In the next step, the final image is formed based on the maximum intensities of the edge detected sub-images. Two sub-images at a time are first merged and result image is formed by merging the maximum intensities of the two already merged images. The result is a single image of the maximum intensity of the thresholded edges of all four images, in a package illuminated from four directions. Last operation of the image fusion stage is a Wiener filtering, which is based on statistics estimated from the 16x16 neighborhood of each pixel to remove background noise in the final image.

E. Binarization

Binarization is an important step in segmenting text characters. Text characters of the merged edge image are next binarized using the Otsu-method in which the optimal threshold is determined automatically from the images grayscale histogram. Method is derived from viewpoint of a discrimination analysis and the optimal threshold is determined by discrimination criterion by maximizing the discriminant measure. Otsu method is robust and computationally efficient [11]. Binarization results in a noise-free image from which unwanted small foreground objects are further filtered out.

F. Post-Processing

Last step of the developed algorithm is to filter small unwanted foreground objects in the binary image using morphological opening operation. During the development of the method, we found it most appropriate to remove connected component objects larger than two pixels. Such objects be may formed during the step of merging the edge images.

Experimental Results

The developed novel text binarization method was tested by dividing the experimental part into two separate steps that form the research pipeline. First step is to perform a black and white text color binarization test for both printing methods and the analyze results. Second step is to test the effect of the haze removal algorithm on the same black and white text color binarization test as in step 1 and analyze the results. In the experimental binarization tests, we used a set of images of a Finnish health technology company taken from real medical packages, of which 52 packages were with pressed, ink marked and 18 pcs with laser printed texts. Packages in the analyzed images are 500-800 mm wide.

The colors of the packages vary while the texts are black or white. The resolution of used grayscale images was 347x656 pixels and image depth was 8-bit. Four images have been taken of each package, with four light sources directed at the target surface of the package. The light sources are aligned against to the package and located diagonally on above, below, on the left and on the right side of the package. One light at a time illuminates the package to be imaged. The camera is placed in front of the package and the camera axis is perpendicular to the plane of the package. Each image set includes a mask image where the area of the package is bright. Expiration date texts consist of ordinary alphanumeric alphabetic characters up to seven characters. Batch code is up to ten characters long. The texts of interest are placed in different places on the target surface of the package which is directed towards the camera. A description of the different curvatures of the analyzed packets is included in the binarization analysis.

A. Text Binarization Using Our Novel Algorithm

First analysis is carried out in Figure 3 that represents a medicine package in which expiration date and batch codes are pressed and ink marked. Target surface of the package is not straight but curves outwards, causing a shadow on the opposite side of the illumination direction:

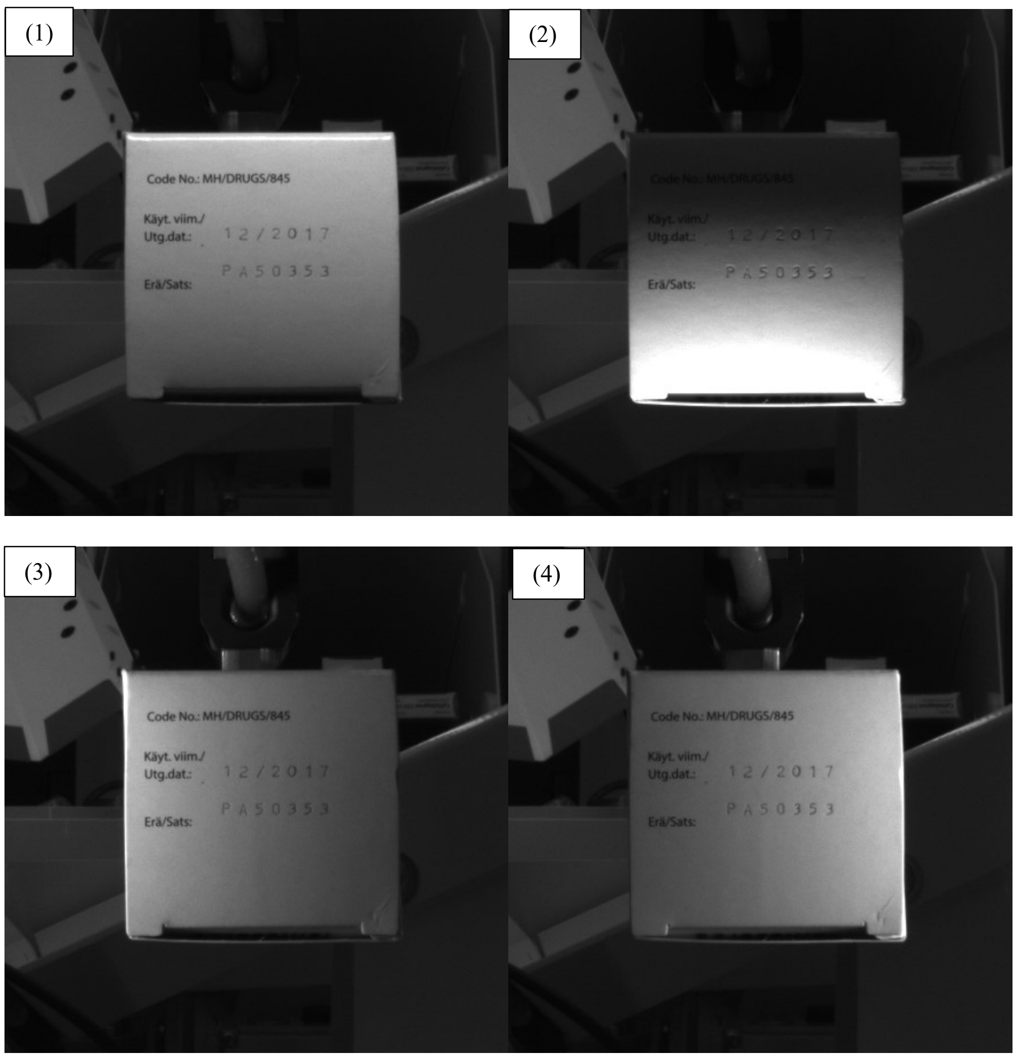


***Figure 3**. Source images 1-4. Pressed and ink marked text. Illuminated from the top (1), bottom (2), left (3), and right (4).*

The resulting image is seen in Figure 4, which indicates the method's binarizing performance of the pressed, ink marked texts. Our novel method enables the text characters to be binarized with the precision of small details despite the curvature of the target surface without noise- and defect-free. Still some pixels are left without binarization of the text characters: Käyt.viim./Utg.dat.: "2" Erä/Sats: "P", "A" and "5".

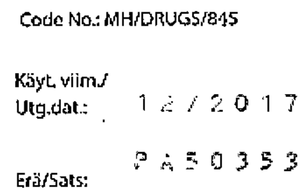


Figure 4. Binarization result obtained for images from the medicine packages used in experiments shown in Figure 3 for our novel method (image inverted to improve visibility).

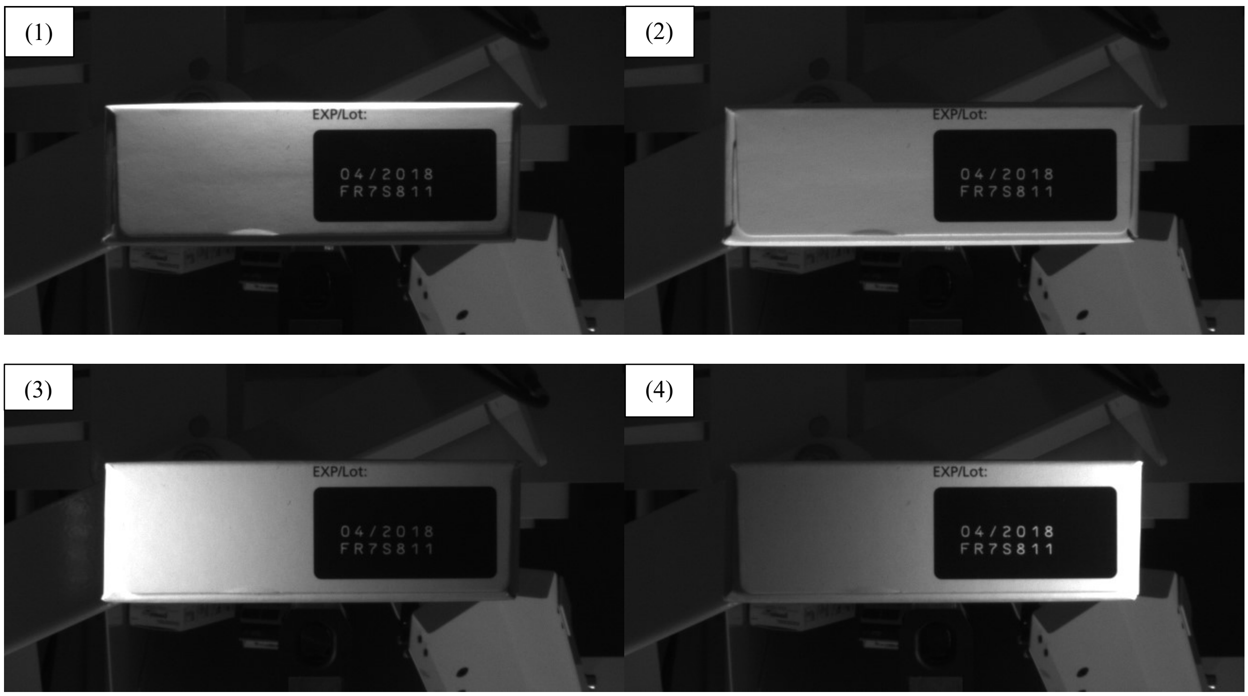


***Figure 5**. Source images 1-4. Laser marked text. Illuminated from the top (1), bottom (2), left (3), and right (4).*

The resulting image is seen in Figure 6, which indicates the method's binarizing performance of the laser-marked texts on an almost flat package. Texts are binarized noise-free and defect-free. However, the binarizing the shape of the font edges has remained incomplete

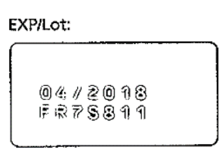


***Figure 6**. Binarization result obtained for images from the medicine packages used in experiments shown in Figure 5 for our novel method (inverted image to improve visibility).*

B. Effect of Haze Removal Algorithm

After the binarization performance test, a haze removal step of the algorithm was included in our developed novel method before edge detection step. In this way, the effect of the haze removal algorithm to the binarization results could be analyzed. First analysis with haze removal algorithm was performed on the medicine package of Figure 3. The resulting image is seen in Figure 7, which indicates the method's binarization performance with haze removal algorithm. Clearly, the entire area of the text of interest is binarized evenly by the effect of the haze removal algorithm:

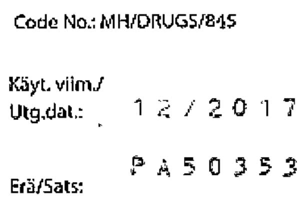


Figure 7 Binarization result obtained for images from the medicine packages used in experiments shown in Figure 3 for our novel method with haze-removal algorithm (inverted image to improve visibility).

Figure 8 indicates the performance of our novel method on a laser-marked flat package resulting an intact binarized sharp-edged, clearly distinguishable characters from the background:

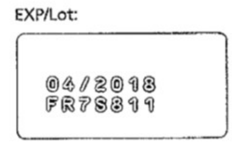


Figure 8. Binarization result obtained for images from the medicine packages used in experiments shown in Figure 5 for our novel method with haze-removal algorithm (inverted image to improve visibility).

Conclusion and Future Work

The text recognition of cardboard pharmaceutical packages using photometric imaging was studied and our novel developed method for expiration date and batch code texts binarizing was presented.

The achieved binarization results with the developed algorithm whose image analysis is based on sub-images adaptive filtering, haze removal algorithm, and fusion of edge detected sub-images seem to be very promising and allow binarization of interesting texts even from the surfaces of variably curved packages. Image binarization, in which the pixels of text characters are identified from background and further segmented, is a critical step operation of OCR. Therefore, special focus will need to be attached to development of a robust binarization method.

Based on our experimental results presented in this paper, the role of the haze removal algorithm is important in the binarization of low light images with the texts that are difficult to distinguish from the packages background. With it even the edges of text characters binarization is robust on a curved surface. Without haze removal algorithm, some small edge parts of text characters are not accurately binarized from the background. The haze removal algorithm improves the binarization accuracy of the individual pixels of these text characters and further enables high-quality segmentation of texts of interest and optical character recognition.

In our future research work, we will focus on the binarization of background-colored texts and the segmentation and processing of binarized texts with optical text recognition and a neural network solution. The main goal is to develop a solution that is capable of automatic text recognition of the expiration date and batch codes made with different printing methods.

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Author Biography

Jarmo Koponen received a bachelor's degree (2018) and a master's degree in software engineering from the University of Eastern Finland (2019). Since 2020, he has worked in the University of Eastern Finland as a project designer and PhD student. He has +20 years of international work experience in development of machine vision systems for the paper and mining industries, whereof +15 years at Honeywell. in his current work, he has focused on the OCR techniques.

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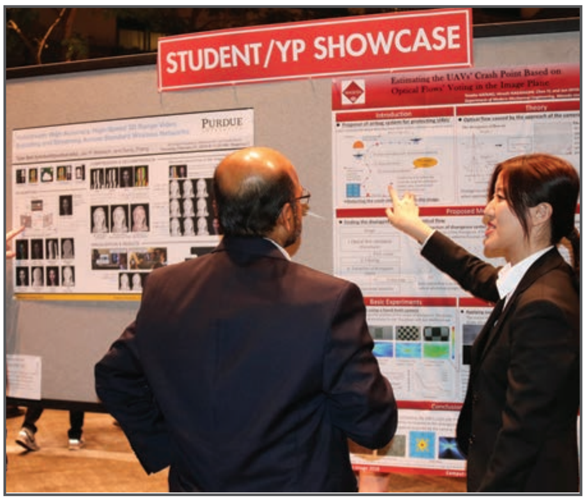

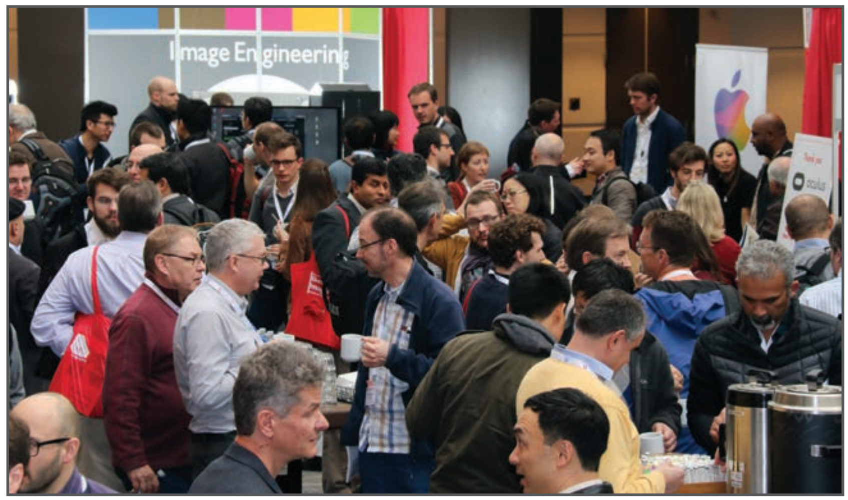

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